Flow Proportional Sampling Techniques

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Flow Proportional Sampling

- Individual sample (aliquot) collection interval is determined by variation in discharge flow.
- Requires some type of flow meter.
- Flow meter (or other output) provides trigger signal to sampling equipment.
- Variable number of samples.
- Requires knowledge of discharge volumes and pumping rates.
- How much composite volume do you need for analysis?
Time Proportional vs. Flow Proportional

- **Time proportional:**
  - Fixed aliquot volume at defined time interval (i.e. once per 15 minutes)

- **Flow proportional:**
  - Fixed aliquot volume at defined flow volume interval (i.e. once every 1000 gallons), OR
  - Variable aliquot volume at defined time interval.
Flow Proportional Variable Aliquot Volume Issues

Variable aliquot volume at defined time interval can be difficult to set.

- Sampling equipment may not support this method.
- Time interval may not coincide with cyclic discharges.
- Always catching high discharge flow volumes may cause sampler to reach maximum composite volume before end of monitoring period.
- Always catching low discharge flow volumes may cause sampler to not take enough composite volume for analysis.
Time Constant Variable Volume (Problem Scenario)

Flow (gallons per minute)

Time

9:00 9:30 10:00 10:30 11:00 11:30

Sample Event
Flow
Why would we want to use flow proportional sampling?
Sampling Scenario (Time Composite)

- Sampler collects 26 aliquots during low flow (8pm to 9am).
- Water during low flow is clean water from treatment process (approx. 5 gpm).
- Half of composite volume is essentially clean water, so composite sample results are diluted nearly 50%.
- The composite sample is NOT representative of actual discharge.
Sampling Scenario (Flow Proportional)

- Sampler collects aliquots at fixed flow volume interval.
- Water during low flow is clean water from treatment process (approx. 5 gpm).
- Few (if any) samples are collected during low flow.
- Composite sample results are not diluted.
- The composite sample is representative of actual discharge.
Flow Proportional Sampling

• What trigger input does your sampler accept?
  – 4~20mA?
  – Contact closure?
  – 5 to 15volt DC pulse?

• What connector is on your sampler?
  – Brand
  – Size
  – Number of pins

• What pin on the input connector does what?
  – Check schematics in the owner’s manual.

• Be nice to your electrician/electronics specialist!
4 to 20 milliampere (mA) Signal

- A flow meter or other equipment sends a variable current signal to sampling equipment.
- 4mA represents minimum flow.
- 20mA represents maximum flow.
- Above 20mA or below 4mA, metering equipment can be set to show a fault or alarm status.
- The sampling equipment must recognize the 4-20mA signal directly or through some type of interface.
- You must know the minimum and maximum flow rates possible at the discharge site.
- You must know the discharge flow totals.
4 to 20 milliampere (mA) Interface

- Converts 4 to 20mA signal to contact closure.

- At 20mA, the interface contact closures happen at 12 second intervals (5 pulses per minute).

- Known speed allows for calculations to determine the number of pulses per sample event desired.
4 to 20 milliamp Scale Comparison

- Short Circuit in signal cable
  - 22: 100%
  - 21
  - 20
  - 19
  - 18
  - 17
  - 16: 73%
  - 15
  - 14
  - 13
  - 12: 50%
  - 11
  - 10
  - 9
  - 8: 25%
  - 7
  - 6
  - 5
  - 4: 0%
  - 3
  - 2
  - 1
  - 0

- Break in signal cable or other equipment failure
4 to 20 milliamp Scale Comparison

- Short Circuit in signal cable: 22
- Signal Strength in milliamps:
  - 21: 100%
  - 20: 75%
  - 19: 50%
  - 18: 25%
  - 17: 0%
- Break in signal cable or other equipment failure: 0

Pump 1:
- 600 gpm
- 300 gpm
- 0 gpm
4 to 20 milliamp Scale Comparison

- Short Circuit in signal cable
  - 22: 100%
  - 21: 75%
  - 20: 50%
  - 19: 25%
  - 18: 0%

- Break in signal cable or other equipment failure
  - 3: 100%
  - 2: 75%
  - 1: 50%
  - 0: 25%

<table>
<thead>
<tr>
<th></th>
<th>Pump 1</th>
<th>Pump 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal</td>
<td>600 gpm</td>
<td>10 gpm</td>
</tr>
<tr>
<td>Strength</td>
<td>300 gpm</td>
<td>5 gpm</td>
</tr>
<tr>
<td>in milliamps</td>
<td>0 gpm</td>
<td>0 gpm</td>
</tr>
</tbody>
</table>
Contact Closure Signal

- An external flow meter is programmed to trigger a contact closure at a set volume.
- During contact closure, a relay in the flow meter closes momentarily at the set trigger volume.
- Relay closure completes a circuit with the sampler controller triggering a sampling event.
- The Sampler may be set to use more than one contact closure to trigger a sample event.
  - The meter may provide a contact closure every 1,000 gallons.
  - The sampler is programmed to take a sample every 6 contact closures (6,000 gallons)
Contact Closure Operation
Contact Closure Operation
Contact Closure Operation
DC Pulse Signal

- An external flow meter is programmed to deliver a voltage pulse to the sampler at a set volume.
- Typically, the pulse is a 5 to 15 volt DC signal.
- The equipment must be electrically compatible.
  - Voltage, ground and other signal wires to correct pins in connector.
- The Sampler may be set to use more than one pulse to trigger a sample event.
  - The meter may provide a pulse every 1,000 gallons.
  - The sampler is programmed to take a sample every 6 pulses (6,000 gallons)
What is a “Pulse”? 

- A single electrical event recorded by the sampler controller as a count to trigger a sampling event.
- The sampler may be programmed to take a sample by single or multiple pulses.
- Contact closure provides a pulse by feeding a voltage signal from the sampler controller through a relay, and back to the sampler controller.
- 4-20mA converter uses percent of signal scale to perform contact closures at specific rates (i.e. 5 per minute at 20mA). These contact closures provide a pulse to trigger sampling events.
Flow Proportional Sampling

• What connector is on your sampler?
  – Brand
  – Size
  – Number of pins

• What pin on the input connector does what?
  – Check schematics in the owner’s manual.

• Be nice to your electrician/electronics specialist!
Flow Proportional Sampler Setup

• Trigger volume is determined by external meter or by 4-20mA interface.
• Need to know recent discharge flow volumes.
• Potential number of sample events is dependent on maximum flow.
• Sample aliquot volume is determined by potential number of samples programmed and sample container volume.
• Number of sample aliquots taken is dependent on actual discharge flow.
• Composite sample volume is the sample aliquot volume multiplied by the number of actual samples collected (at least it should be...).
Flow Proportional Sampler Setup

Example: Sampler with external flow meter (delivering pulses/contact closures)

- Industry flow has recently been discharging approximately 40,000 gallons per day.
- Industry discharge pump runs at 40 gpm
- Industry flow meter is set to deliver a pulse every 100 gallons.
- Sample composite maximum volume programmed into sampler controller = 10,000mL.
- Target of 48 samples during sampling event (will set to 50 samples for safety factor).
- Sampler takes 43 samples during sampling event.

40,000 gallons per day discharge / 50 potential sample events = 800 gallons per sample event.

800 gallons per sample event / 100 gallons per pulse = 8 pulses per sample event.

10,000mL composite volume / 50 potential sample events = 200mL per aliquot.

43 sample events during discharge X 800 gallons per sample event = 34,400 gallons discharged.

43 sample events X 200mL per aliquot = 8,600mL composited volume.
Flow Proportional Sampler Setup

Example: Sampler with external flow meter (delivering 4-20mA signal)

- Industry flow has recently been discharging approximately 40,000 gallons per day.
- Industry flow meter is set to deliver a 20mA signal at 40 gallons per minute.
- 4-20mA interface module provides 5 pulses per minute at 20mA.
- Sample composite maximum volume programmed into sampler controller = 10,000mL.
- Target of 48 samples during sampling event (will set to 50 samples for safety factor).
- Sampler takes 43 samples during sampling event.

40 gallons per minute flow rate / 5 pulses per minute = 8 gallons per pulse.

40,000 gallons per day discharge / 50 sample events = 800 calculated gallons per sample event.

800 gallons per sample event / 8 gallons per pulse = **100 pulses per sample event**.

10,000mL composite volume / 50 sample events = 200mL per aliquot.

43 sample events during discharge X 800 gallons per sample event = 34,400 gallons discharged.

43 sample events X 200mL per aliquot = 8,600mL composited volume.
4-20mA Sampler Interface Calculations

Example:

Max flow rate at 20mA 100 gallons per minute (GPM)
Min flow rate at 4mA 0 gallons per minute (GPM)
Industry discharge volume 12,800 gallons per day (GPD)
Number of samples desired 48

This interface module provides 5 pulses per minute with a 20mA signal.

Formula #1
Max flow rate at 20mA (GPM) / 5 Flow pulses per minute = Volume in Gallons (Gal/pulse)
100 gallons per minute / 5 Flow pulses per minute = 20 gallons per pulse

Formula #2
Industry average discharge volume in gallons per day / desired number of samples = gallons per sample trigger event
12,800 gallons per day / 48 desired number of samples = 266 calculated gallons per sample trigger event

Formula #3
Trigger volume per sample (gallons) / Gallons per pulse = number of pulses between samples
266 calculated gallons per sample trigger event / 20 gallons per pulse = 13 Pulses per sample

Formula #4
Flow volume per sample event
20 gallons per pulse * 13 Pulses per sample = 260 actual gallons per sample event
Flow Proportional Sampling
(A Balancing Act)

Examples: Decreasing the aliquot volume to allow more sample events.

- Sample composite maximum volume programmed into sampler controller = 10,000mL.
- Individual sample aliquot volume set to = 150mL.
- $10,000\text{mL} / 150\text{mL} = 66$ sample events possible.

The sampler will stop the program after the 66th sample is taken because the controller knows the maximum volume of the composite container is 10,000mL. If the 66th sample event takes place 20 hours into a 24 hour sampling period, the composite does not represent the entire monitoring period. The composite sample is not representative.

Decreasing the aliquot volume allows more samples to be taken during the monitoring period. $10,000\text{mL} / 100\text{mL} = 100$ sample events possible.
Flow Proportional Sampling
(A Balancing Act)

Examples: Decreasing the number of sample events to increase aliquot volume.

- Sample composite maximum volume programmed into sampler controller = 10,000mL
- 120 sample events programmed into sampler.
- 10,000mL / 120 sample events = 83mL per sample.
- Desired aliquot volume is at least 100 mL.

Reduce the number of programmed sample events to increase the aliquot volume.
- Sample composite maximum volume programmed into sampler controller = 10,000mL.
- 100 sample events programmed into sampler.
- 10,000mL / 100 sample events = 100mL per aliquot.
Flow Proportional Sampling
(A Balancing Act)

Examples: Decreasing the number of sample events to increase composite volume.

- Sample composite maximum volume programmed into sampler controller = 10,000mL.
- 120 sample events programmed into sampler.
- 10,000mL / 120 sample events = 83mL per aliquot.
- Sample volume required for analysis is 6,000mL.
- Industry discharge has been consistently triggering only 60 sample events.
- 60 sample events X 83mL per aliquot = 4,980mL composite volume.

Reduce the number of programmed sample events to increase the aliquot volume.

- Sample composite maximum volume programmed into sampler controller = 10,000mL.
- 80 possible sample events programmed into sampler.
- 10,000mL / 80 sample events = 125mL per aliquot.
- 60 actual sample events X 125mL per aliquot = 7,500mL composite volume.
Flow Proportional Sampling
(A Balancing Act)

Examples: Change the number of pulses to account for greater discharge flow.

- Sample composite maximum volume programmed into sampler controller = 10,000mL
- 96 sample events programmed
- Flow meter set for pulse event every 20 gallons of discharge flow.
- Sampler set for sample event every 10 pulses.
- 20 gallons X 10 contact closures = 200 gallons per sample event.

The sampler will stop the program after the 96th sample is taken.
- 96 sample events X 200 gallons per sample event = 19,200 gallons of discharge flow.

If the industry discharges more than 19,200 gallons of process water during the 24 hour sample event, the sample event does not cover the entire sampling period and is invalid.

Change the number of pulses at the sampler to allow for greater discharge flow.
- 20 gallons X 15 pulses = 300 gallons per sample event.
- 96 sample events X 300 gallons per sample event = 28,800 gallons of discharge flow.
Flow Proportional Sampling
(A Balancing Act)

Why program the sampler for more than 1 pulse per sample event?

To allow for adjustment of sample frequency as flow changes.

- Industry flow meter set for 1 pulse every 1,000 gallons.
- Industry discharge is 24,000 gallons per day.

24,000 gallons per day / 1,000 gallons per pulse = 24 pulses per day.
A maximum of 24 samples can be taken at these settings. There is no real programming flexibility with these settings. The sampler would only be able to be programmed for 1 pulse.

Change the flow meter to 1 pulse every 100 gallons.
24,000 gallons per day / 100 gallons per pulse = 240 pulses per day.
The sampler can be programmed to collect a sample at different pulse settings as discharge flow changes. The sampler can be programmed for 1 to 10 pulses with these settings, allowing much more flexibility with setup.
Flow Proportional Sampling

Examples: Changing flows affect sampling.

Industrial User Daily Flow Data (gallons):

<table>
<thead>
<tr>
<th>Period</th>
<th>Min.</th>
<th>Max.</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/1/13 to 5/31/13</td>
<td>5,000</td>
<td>9,000</td>
<td>7,000</td>
</tr>
<tr>
<td>6/1/13 to 6/30/13</td>
<td>6,000</td>
<td>12,000</td>
<td>10,000</td>
</tr>
<tr>
<td>7/1/13 to 7/31/13</td>
<td>5,000</td>
<td>18,000</td>
<td>13,000</td>
</tr>
<tr>
<td>8/1/13 to 8/31/13</td>
<td>8,000</td>
<td>16,000</td>
<td>11,500</td>
</tr>
<tr>
<td>9/1/13 to 9/30/13</td>
<td>12,000</td>
<td>17,500</td>
<td>14,750</td>
</tr>
</tbody>
</table>

- Industrial users may have swings in production volumes that affect effluent discharge.
- Flow settings based on May data may be insufficient for September sampling.
- Look at flow data over various periods of time.
- Consider quarterly, semi-annual, or annual averages when determining flow settings.
Flow Proportional Sampling

Examples:  Changing flows affect sampling.

Industry flow meter and sampler set to take 1 sample every 100 gallons. Sample maximum composite volume is programmed at 10,000mL.

**Industrial User Daily Flow Data (gallons):**

<table>
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<tr>
<th>Date Range</th>
<th>Min.</th>
<th>Max.</th>
<th>Avg.</th>
</tr>
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<tbody>
<tr>
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<td>7,000</td>
</tr>
<tr>
<td>6/1/13 to 6/30/13</td>
<td>6,000</td>
<td>12,000</td>
<td>10,000</td>
</tr>
<tr>
<td>7/1/13 to 7/31/13</td>
<td>5,000</td>
<td>18,000</td>
<td>13,000</td>
</tr>
<tr>
<td>8/1/13 to 8/31/13</td>
<td>8,000</td>
<td>16,000</td>
<td>11,500</td>
</tr>
<tr>
<td>9/1/13 to 9/30/13</td>
<td>12,000</td>
<td>17,500</td>
<td>14,750</td>
</tr>
</tbody>
</table>

July data: 5,000 gallons / 100 gallons per sample event = 50 sample events. 18,000 gallons / 100 gallons per sample event = 180 sample events.

A difference of 130 sample events is possible from day to day discharge flows.

10,000mL composite volume / 50 sample events = 200mL aliquot volume.
Flow Proportional Sampling

Examples: Changing flows affect sampling (continued).

10,000mL composite volume / 180 sample events = 55mL aliquot volume.

Is the aliquot volume sufficient? This may require a change in meter/sampler settings.

If the sampler is programmed to handle the maximum flow of 18,000 gallons, and the daily discharge flow is 5,000 gallons:

55mL aliquot volume X 50 sample events = 2,750mL composite volume.

Is this enough volume for analysis?
Flow Proportional Sampling

Examples: Change in equipment without notification.

Industrial User Daily Flow Data (gallons):

<table>
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<tr>
<th>Period</th>
<th>Min.</th>
<th>Max.</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/1/13 to 5/31/13</td>
<td>8,000</td>
<td>9,000</td>
<td>8,900</td>
</tr>
<tr>
<td>6/1/13 to 6/30/13</td>
<td>8,000</td>
<td>9,000</td>
<td>8,700</td>
</tr>
<tr>
<td>7/1/13 to 7/31/13</td>
<td>8,000</td>
<td>9,000</td>
<td>8,800</td>
</tr>
<tr>
<td>8/1/13 to 8/31/13</td>
<td>8,000</td>
<td>9,000</td>
<td>8,700</td>
</tr>
<tr>
<td>9/1/13 to 9/30/13</td>
<td>8,000</td>
<td>9,000</td>
<td>8,900</td>
</tr>
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</table>

- The industry discharges water 16 hours per day.
- The discharge rate has a maximum of 10gpm.
- The industry has VERY consistent discharge volumes.
- Beginning in July, the sampler began taking half as many sample aliquots as in previous months. Sampler settings are the same as in previous months.
- All sampling events since July have had low composite volume because of fewer sample aliquots.
Flow Proportional Sampling

Examples: Change in equipment without notification.

Declared original maximum pump output flow is 10 gpm.
Normal production is 16 hours per day.
16 hours x 60 minutes/hour x 10 gpm = 9,600 gallons expected maximum.
Effluent flow meter 20mA signal is set to 10 gpm.

In July, the pump was replaced by a unit capable of 20 gpm.
16 hours x 60 minutes/hour x 20 gpm = 19,200 gallons
Effluent flow meter 20mA signal has been set to 20 gpm, but the pump is never run more than 10 gpm.
No notification of the equipment change was made to the sampling technician.

In this scenario:
With the new pump operating at the 10 gpm pumping rate, the flow signal is no longer 20 mA.
The flow signal will be never be higher than 12 mA (50% of the maximum signal strength)
Using the original programming for the site, the sampler will draw half as many samples as events in
Flow Proportional Sampling

In Conclusion:

• Read your equipment manuals, learn about the hardware.
• Document the flow settings for the sample site.
• Document the calculations for the sampler/meter settings.
• UPDATE the flow settings for the sample site on a regular basis.
• Pay attention to changing trends in discharge flow volumes.
• Use the flow data to determine appropriate number of sample events.
• Communicate with equipment vendors, manufacturers, and support sites.
• Communicate with Industrial Users.
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